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STRATIGRAPHY OF THE WAVERLY FORMATIONS OF CENTRAL AND SOUTHERN OHIO¹

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PART I

CLASSIFICATION

The following columns of formations (Table I) in as many different regions are presented chiefly to indicate the members composing the Cuyahoga in its different facies. To these have been added the other formations with some duplication of names so that the columns are somewhat more than a classification; they are a partial correlation table. The top of the Cuyahoga on the Ohio River, as explained later, is the stratigraphic equivalent of the lowest part of the Byer member farther east and north. The amount of equivalency cannot be exactly indicated.

The names Vinton, Allensville, Byer, Berne, Fairfield, Lithopolis, Churn Creek, Vanceburg, Rarden, Henley, and Portsmouth are new formational names,¹ and the name Buena Vista is applied somewhat differently from its original usage but not with a wholly new meaning. The name Raccoon is adopted from Hicks.²

In presenting a summary of the findings of several years' work in this field it is impossible to cite any but the chief facts. The presentation of the large body of evidence on which these conclusions rest, soundly it is believed, must await the completion of the work now being prosecuted on the faunas of the region. Such

¹ The names Vinton, Allensville, and Byer were first used without definition in a chapter by the writer entitled, "The Geological History of Fairfield County, Ohio," in the *History of Fairfield County*, pp. 203-23 (Chicago: Richmond-Arnold Publishing Co., April 15, 1912). The names were applied to the respective members in Fairfield County but they were not defined. They are here defined for the first time.

² L. E. Hicks, *Am. Jour. Sci.*, 3d. Ser., XVI (1878), 216.

TABLE I

CENTRAL FAIRFIELD AND HOCKING COUNTIES		CENTRAL LICKING COUNTY		EASTERN LICKING COUNTY	
Logan formation	{ Vinton member Allensville member Byer member } { Black Hand member Fairfield member Lithopolis member }	Logan formation	{ Vinton member Allensville member Byer member } { Black Hand member Raccoon shales, top only seen, rest known from wells }	Logan formation	{ Vinton member Allensville member Byer member } { Black Hand member "Sandstones" (wells) "Shales" (wells) }
Cuyahoga formation, Hocking Valley con- glomerate facies		Cuyahoga formation, Granville shale facies		Cuyahoga formation, Toboso conglomerate facies	
Sunbury shale		Sunbury shale (wells)		Sunbury shale (wells)	
Berea Grit		Berea Grit (wells)		Berea Grit (wells)	
Bedford formation		Bedford formation (wells)		Bedford formation (wells)	

SOUTHWESTERN SCIOTO COUNTY		CENTRAL ROSS, PIKE, AND SCIOTO COUNTIES	
Logan formation not subdivided		Logan formation not subdivided	
Cuyahoga formation, Vanceburg sandstone facies	{ Churn Creek member Vanceburg member Rarden member Buena Vista member Henley member }	Cuyahoga formation, Scioto Valley shale facies	{ Portsmouth member Buena Vista member Henley member }
Sunbury shale		Sunbury shale	
Berea Grit		Berea Grit	
Bedford formation		Bedford formation	

relationships as would necessitate even brief discussion of facts for and against alternate interpretations have been passed over.

It is obviously impossible even to mention the results obtained by many previous workers who have contributed, often fundamentally, to the subject. The stratigraphy of the upper part of the Waverly had been studied in detail in a single small region only, in central and eastern Licking County, near the center of the state, and at the northern end of the area herein considered. Hicks in 1878 gave a brief description of the formations of this limited region and Herrick in the eighties described other subdivisions, particularly with reference to the faunas. Prosser¹ in 1901 reviewed the work of previous writers on the stratigraphy, adopted the subdivisions made by Hicks and Herrick, applied to them the proper geographical names, and described in detail some of the sections in the region. Prosser's description of the sections at Newark, subdivided after Hicks and Herrick, is the one generally quoted in more or less detail as representing these formations in Ohio.

It is not surprising to find that, as a result of the changed perspective afforded by detailed work over a much wider area, the subdivisions adopted by Prosser in this section must be revised. In fact, both Hicks and Herrick failed to correlate correctly the members across this small area in Licking County which they studied in some detail. In addition, it appears that one member, described as a formation, the Black Hand, is not as important stratigraphically as some members that were not particularly distinguished by the earlier workers.

In Table II are given the subdivisions of the Newark section as stated by Prosser, and in a parallel column the ones herein adopted for the same section. This will serve to show the extent to which the interpretation of the section has been altered.

It will be noted that the names Cuyahoga and Logan are retained for two chief terranes, and these are extensively subdivided into members. These have been recognized as two chief terranes of

¹ *Jour. Geol.*, IX (1901), 205-31. The Quarry Run section is described on pp. 221-26. Other outcrops seen later led to a second description of this section with certain changes in interpretation. This was published in 1904, *American Geologist*, XXXIV, 358-61.

the Waverly for forty years. When the errors of interpretation and correlation of various geologists during this length of time are resolved out, it is peculiar that, after all the different applications that have been made of these names, it should now fall to them to denote precisely the same beds that they were originally applied to forty years ago, or, as nearly as can be determined, the central Ohio equivalents of these beds. The subdivisions of the Logan here adopted constitute exactly the Logan formation at Logan, the locality from which E. B. Andrews named it in 1870, since when the

TABLE II

Proposed Classification		Prosser	
Logan formation	Vinton member	Logan formation	
	Allensville member	Conglomerate II	Black Hand formation
	Byer member	<i>Allerisma</i> shale	
Cuyahoga formation	Berne member	Conglomerate I	
	Black Hand member		
	Raccoon shales, only a few feet exposed	Cuyahoga formation	

name Logan has been used with precisely the same meaning by no other writer. The Cuyahoga was named from outcrops on the Cuyahoga River in northern Ohio where it is overlain by the Pennsylvanian, the whole of the Logan and some of the Cuyahoga having been removed by pre-Pennsylvanian erosion. It is not, at present, possible to demonstrate that the beds to which the name Cuyahoga is here applied are the precise equivalent of the beds in the type section; but it is now evident that they are almost or quite identical with those shales in the shale facies in central Ohio which Orton knew lay between the Berea Grit and the Logan, which he called Cuyahoga, but of which he never fixed the precise limits.

This does not imply that any of these workers understood the true relationships. They did not; none of them knew that the Black Hand (or Waverly conglomerate as it was called) and the underlying coarse sandstones (which indeed were practically

unknown) are merely a facies of the Cuyahoga, and the attempts, particularly by Orton, properly to place these conglomerates in the Waverly column led to confusion. He included the Black Hand with Andrew's Logan under the term Logan Group, a procedure that has been followed by many.

Yet, in spite of the fact that these names are now made to denote the same beds that they denoted in the earliest usage in central Ohio, a question may be raised by some whether they should be retained; whether it is established that these subdivisions are two chief subdivisions, and that a classification which would drop one or both terms and place some of the members here proposed in a higher rank would not more nearly indicate the true relations. Prosser in his work in northeastern Ohio has dropped the term Cuyahoga¹ and builds this portion of his Waverly column out of members which were formerly units within the Cuyahoga. From this it would appear that he does not regard the Cuyahoga shale, as delimited by Newberry in northern Ohio, as a terrane of established stratigraphic significance.

Apropos of this question it may be remarked that in the present work it has been found exceedingly convenient to retain both. The classification of the Cuyahoga of central and southern Ohio here proposed with its numerous members in different facies is very complex; nevertheless, when the entire area is considered, it appears that these groups of members constitute a distinct terrane, for no one of its members in any facies can be satisfactorily discussed except in connection with the other members of that facies. Furthermore, the Berne member, whether it be regarded as closing the Cuyahoga or opening the Logan, separates two groups of sediments that are essentially different from each other in many ways. The retention of the term Logan is necessary, for although easily subdivided into three important members over most of this area, along its southwestern margin it is not so divisible and one name is needed to denote sediments that are there the equivalent

¹ "The Devonian and Mississippian Formations of Northeastern Ohio"; *Geol. Surv. Ohio*, 4th ser., *Bull.* 15 (1912), 574 pp.

of all three a few miles to the eastward. It is true, as will be pointed out, that on the Ohio River the lower part of the Logan sandstones pass into shales that are, so far, indistinguishable from the upper part of the Cuyahoga and are included in the upper part of the Cuyahoga. Nevertheless, for the reasons just stated, the conceptions of Logan and Cuyahoga are exceedingly convenient ones, whatever may be their actual stratigraphic importance to be determined later. Final decision should be reserved until the evidence of the faunas can be presented.

Perhaps the greatest innovation from the Waverly column as heretofore established is the reduction in rank of the Black Hand formation. This had come to be regarded as a distinct formation between the Cuyahoga and Logan, a stratigraphic unit that had to be considered in any attempt at correlation of rocks of this general age. It is, however, a local development of the Cuyahoga and is, apparently, not as important a stratigraphic unit as any one of the three members of the Logan.

BEDFORD AND BEREAL FORMATIONS

In the classification of the Waverly formations here presented, the Bedford formation has been included. By such inclusion it is not intended to express any opinion in the discussion now being waged as to whether this formation should be placed in the Devonian or should be retained in the Waverly as was the practice for many years; it is here retained largely because such has been the practice. The present discussion does not attempt to correlate this or other subdivisions of the Waverly with the standard time scale because that would involve discussion of the faunas, a subject not yet ready for presentation. An earlier paper by Hyde on a special phase of the Bedford and Berea gives their general character in southern Ohio although by no means a summary of the various problems connected with them.¹

One feature there mentioned should be emphasized. Since that paper was published several papers have appeared describing the unconformity between the Bedford and the Berea in northern and

¹ *Jour. Geol.*, XIX (1911), 257-69.

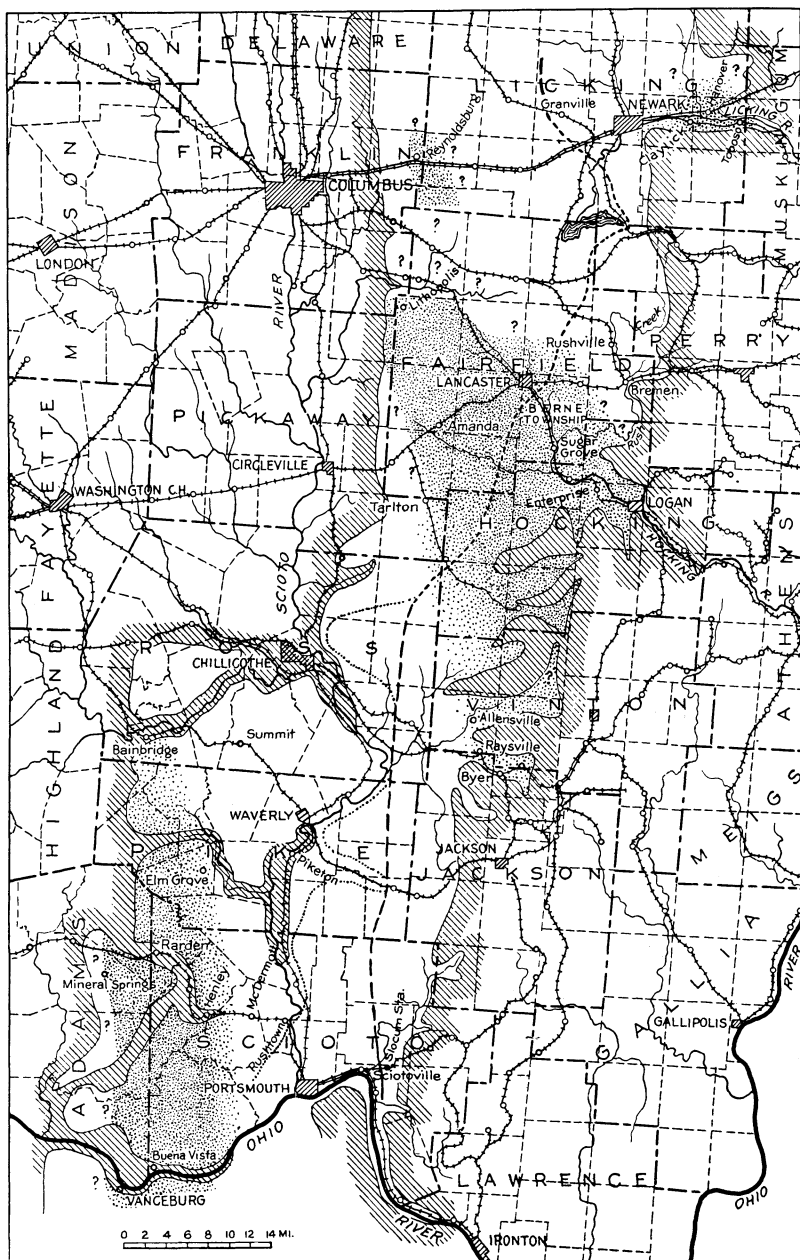


FIG. 1.—A. Map showing outcrop belt of Waverly formations of central and southern Ohio, bounded on the western side by Devonian and Silurian rocks, on the eastern side by the Pennsylvanian. These boundaries are drawn only approximately and are generalized. The conglomerate and sandstone facies of the Cuyahoga are stippled, at the northward the Toboso conglomerate area, near the central portion the Hocking Valley conglomerate facies, and in the southwestern part the Vanceburg facies; intervening are the Granville and Scioto Valley shale facies. Question marks indicate uncertainty due to removal by erosion, burial beneath glacial deposits, or unobserved areas. The known western margin of the Allensville member of the Logan is represented by a line east of the center of the Waverly belt. Near the Ohio River its actual stratigraphic western limit is represented by a continuous line. From there northward to Hocking County its known westernmost occurrences are represented by coarse dashes—the horizon occurs possibly as far west as the dotted line and its disappearance westward is known in northern Scioto County, but the precise zone of disappearance is not located. From Hocking County northward it extends as far west as the westernmost outcrops of its horizon, represented by short dashes.

central Ohio.¹ In view of the debated age of the Bedford, such an unconformity, if widespread, would be urged, and indeed it has already been suggested by Prosser,² Girty³ and Burroughs⁴ as evidence for the separation of the Bedford from the remainder of the Waverly and of its affiliation with the Devonian. It is therefore important to emphasize that there is no evidence seen by the writer south of Lithopolis in Fairfield County of the existence of any such plane of unconformity. There is irregularity at the plane which in some sections appears to be this contact, but apparently of the same kind and of no more importance than many other similarly irregular bedding planes, often in the same section, and not of a nature, so far as observed by the writer, to warrant description as evidence of erosion. On the other hand, at many localities, there is a gradation from the Bedford to the Berea, sometimes abrupt, elsewhere gradual. The Berea of southern Ohio is only a phase of the Bedford; they consist of precisely the same kind of sediments with the same ripple-marked structure, a sedimentary structure so peculiar and unusual that its occurrence in both Bedford and Berea cannot be urged as an insignificant coincidence by anyone at all familiar with sandstone formations and their structures. Almost the only distinguishing feature between them is that the sandstone beds are

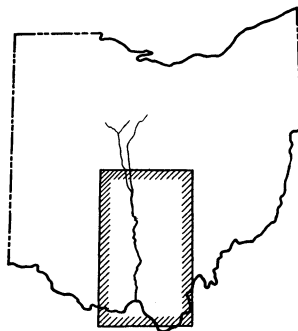


FIG. 1.—B. This outline map is a guide map to indicate the position in Ohio of the area mapped in the large one.

¹ W. G. Burroughs, "The Unconformity between the Bedford and Berea Formations of Northern Ohio," *Jour. Geol.*, XIX (1911), 655-59; C. S. Prosser, "The Disconformity between the Bedford and Berea Formations in Central Ohio," *ibid.*, XX (1912), 585-604; C. S. Prosser, "The Devonian and Mississippian Formations of Northeastern Ohio," *Geol. Surv. Ohio*, 4th ser., *Bull.* 15 (1912); W. G. Burroughs, *Economic Geol.*, VIII (1913), 480-81; "Berea Sandstone in Eroded Cleveland Shale", *Jour. Geol.*, XXII (1914), 766-71.

² C. S. Prosser, *Geol. Surv. Ohio*, 4th ser., *Bull.* 15 (1912), 511, 512.

³ George H. Girty, "Geological Age of the Bedford Shale of Ohio," *Annals New York Acad. Sci.*, XXII (1912), 296.

⁴ *Jour. Geol.*, XXII, (1914), 771.

relatively thicker and the shales relatively thinner in the Berea, and some, not all, of the sandstones of the Bedford are slightly calcareous, never enough so to be called an impure limestone. Furthermore, the same structure in the Berea sandstone generally in central Ohio and at the only one of the localities seen by the writer, Lithopolis, where the unconformity is present, shows that the Berea above the unconformity in central Ohio is of much the same type as, and is at least closely related to, the Berea of southern Ohio, and presumably is not widely different from it in age.

SUNBURY SHALE

The Sunbury shale is a thin bed of black, fissile shale present over the entire area here considered, either on outcrop or under cover. Of it no more need be said in view of Prosser's excellent description of its features,¹ except that it with the subjacent Berea has been invaluable as a base from which to pursue work in the complex overlying formations.

CUYAHOGA FORMATION

THE FACIES

The Cuyahoga formation has for years been described as a shale formation. It is true that sandstone members, sometimes of great economic importance, have been known to occur in it at various points, and thin sandstones in greater or less abundance have always been recognized as a component throughout its thickness. However, the descriptions which have appeared in print have generally been such as to give the impression that it is largely a body of shales and not a great deal more complicated than the formations below it. This is owing to the fact that portions of the massive sandstone and conglomerate facies were not recognized as Cuyahoga but were considered a distinct horizon, the Black Hand formation, or, under the name Logan conglomerate, were considered a part of the overlying Logan formation, while the remaining portions of these same sandstones were practically unknown.

The Cuyahoga formation may be made up very largely of shales in one area but of sandstones or conglomerates in adjacent areas

¹ *Jour. Geol.*, X (1902), 262-312.

at no great distance. Furthermore, in any such area, the sediments are likely to remain much the same from the bottom of the formation to its top. That is, in a sandstone or conglomerate area we may expect to find sandstones or conglomerates or sandy shales more or less continuously throughout the formation, and in a shale area the sandstones are likely to be thin or inconspicuous. This is due to localized conditions of sedimentation which prevailed during Cuyahoga time. The result is that distinct depositional facies can be recognized with pronounced uniformity in the lithology of the vertical column in any one area, except in the regions of transition from one facies to the adjacent one.

It is necessary to recognize five such facies. Beginning in Licking County and passing southward across the outcrop (see outline map), these are (1) the *Toboso facies*, an area in which the sediments are largely non-fossiliferous conglomerates and sandstones with shales in the lower part; (2) the *Granville facies*, mostly shales with finer-grained fossiliferous sandstones in the upper part, conglomerates absent or limited to a few thin beds; (3) *Hocking Valley conglomerate facies*, mostly conglomerates and coarse sandstones with some shale, fossils wanting; (4) *Scioto Valley shale facies*, argillaceous shales with thin sandstone beds tongued into them from the provinces on either side, fossiliferous; (5) the *Vanceburg sandstone facies*, an area in which are developed sparingly fossiliferous sandstones of a different type from those in the conglomerate areas.

Within these facies, the Cuyahoga is composed of distinct lithological members, which can be traced in regular succession over much or all of the facies and sometimes into the adjacent facies. It is these relationships that have given rise to the complex classification here presented.

There is also to be noticed, before taking up the facies in detail, the fact that they all have a pronounced axial trend from north-northwest to south-southeast, and that this axial trend does not correspond to the direction either of the strike or of the dip of the series, but is intermediate between them. As a result the area of any one of these facies extends diagonally across the outcrop belt of the Cuyahoga.

The northern limit of the present work in Licking County is by no means a logical one; it cuts through the heart of the Toboso conglomerate facies. Besides, conglomerate areas have been reported from Knox County to the northward which may be at about the same horizon and in which certain structures are reported which are also found in the Toboso and Hocking Valley provinces.¹ This conglomerate may be at a higher horizon, as its base appears to be about 965 feet above the base of the Bedford shale. Whether they are a continuation of the conglomerates of the Toboso province or whether they belong to a distinct facies is not certainly known, but apparently they are distinct. Other conglomerates of a yet more uncertain horizon are reported from yet farther north in the north-eastern part of Richland County,² southern Ashland,³ and in Wayne County⁴ where G. F. Lamb describes two conglomerate horizons.

The two conglomerate areas considered in this paper, the Toboso and Hocking Valley, have much in common. Lithologically and in the structure of their beds they are very closely related, and both have clearly been formed in much the same way. The other sandstone facies, the Vanceburg, is wholly different in these and in other respects. Furthermore, the Granville shale facies lying between the two conglomerate areas, although lying mostly below drainage and hence inaccessible except by well-records, is clearly influenced largely by their proximity. The Black Hand and Berne members lying at the top of the Cuyahoga in the conglomerate areas possibly in places under cover extend entirely across the Granville facies, although the former in part passes into shale in its surface outcrops. In fact, it seems very probable that the Toboso and Hocking Valley conglomerate areas are merely lobes extending northwestward from a much larger conglomerate area lying under cover of the Coal Measures at no great distance to the southeastward, and that the Granville shale province is the accumulation of shales with considerable sandstone lying between these lobes. The Scioto shale facies is not influenced to nearly such an extent by the adjacent sandstone areas.

¹ *Geol. Surv. Ohio*, III, 337, 338.

² *Ibid.*, pp. 317-18.

³ *Ibid.*, p. 523.

⁴ *Ibid.*, p. 539; also G. F. Lamb, *Ohio Naturalist*, XIV (1914), 344-46.

THE TOBOSO CONGLOMERATE FACIES

Extent and thickness.—The conglomerates of this facies are exposed typically in the east-central part of Licking County. The areal extent is unknown to the writer, since it has not been traced to the northward, and observation has been confined to the excellent outcrops seen within two or three square miles in the vicinity of the post-glacial gorge of the Licking near Toboso and Hanover. It seems very likely that it is small and not at all comparable with the great Hocking Valley area. The entire observable width is less than three miles, since the Black Hand passes below drainage immediately east of Toboso, as a result of regional dip to the eastward.

The thickness of the Cuyahoga in this area is about 588 feet (gas well at Everett glass-sand plant above Toboso where the upper 340 feet are reported as "sandstone," the remainder as "shale"). Of this, only the topmost 100 feet are exposed above drainage. It was to this exposed 100 feet of conglomerate in the gorge of the Licking that Hicks gave the name Black Hand, from Black Hand Rock near Toboso. From the original Black Hand of Hicks, the topmost foot or two are now separated by the writer as the Berne member.

The Black Hand member.—This member of the Toboso facies is a massive, coarse quartz sandstone with abundant quartz pebbles which are seldom over an inch in diameter and usually half an inch or less. It is pure enough to be used for glass sand after washing. The color is usually yellow or buff, sometimes reddish. Fossils, worm trails excepted, have not been recorded.

The structure of this member is of significance. The sandstones within 10 or 15 feet of its top lie horizontally or nearly so. Below this the bedding of the remainder of the exposed portion, 55 or 60 feet, is inclined, in general, to the northward at angles of from 5° to 15° , 10° being usual. On the western side of the area, that is, near and to the southward of Hanover, the dips are slightly northwest, the strikes ranging from due east and west to N. 80° E. Farther east, and observed especially on the Licking River, the dips swing to east of north, the strikes ranging from N. 80° W. to N. 50° W. This difference in the dips on the east and west sides of

the area within short distances suggests strongly that this conglomerate mass is not one of great extent, and that the more easterly outcrops are really on the eastern side of the conglomerate area. That these are true beds is shown by the occasional occurrence of ripples on their upper surfaces or of a very thin parting of clay shale between two inclined sandstone beds. Such a feature may be found along a bedding-plane from the point of its emergence near stream level to its disappearance near the top of the inclined beds.

Although the inclination of the larger beds of the region is quite regular, the structure within these beds presents the greatest diversity. The material is very coarse sand with abundant pebbles, and evidence of strong current action is seen. Cross-bedding is everywhere present in the inclined portions. These minor structures follow no appreciable order. The cross-bedding is in any direction. It may be in opposite directions in superjacent beds and often is inclined directly against the slope of the larger beds, contradictory as it may seem. Erosion planes are abundant; although local and limited in extent, these are true local erosion planes which can frequently be traced for many yards along an outcrop, and appear to be distinct from the small cuttings which are always found where there is evidence of current action and which are usually referred to simply as cross-bedding. To the eastward the Black Hand goes under cover with these structures yet present, but on the western side of the conglomerate area the bedding gradually flattens out and the current structures and cross-bedding disappear together with the pebbles, so that within a mile or two the member becomes a more or less structureless (except for ordinary bedding-planes), coarse sandstone. This is the way it occurs at Clay Lick only two and one-half miles west of where the structures are at their maximum of development. And only a short distance west of Clay Lick, thin clay shales begin to appear below the massive upper 100 feet or Black Hand member. These suggest that the Granville shale province is being approached and also fairly well demonstrated that the upper 100 feet more or less of sandstones in the Toboso province constitute a member distinct from the sandstones below it reported in the well.

Hicks¹ noticed the general northerly dip of these beds and the oblique lamination dipping in all directions and considered it the structure of a sea beach. No worker since has paid any attention to this acute observation or its significance, and Herrick derived the material from the northeast, flatly contrary to the evidence of the structure.²

The Berne member.—At the top of the conglomerates is found, at all points, one or two feet of coarser, more pebbly conglomerate. This is designated the Berne member. Its discussion is reserved to the consideration of the Hocking Valley conglomerate area.

Origin of the conglomerates.—It is evident that the sandstones and conglomerates of this area were derived from the south-southeastward. It is true that only the upper sixth of the thickness is exposed, but it appears, from the structures observed in the Hocking Valley conglomerate area, that the statement may safely be applied to the entire thickness. It appears that the visible portion of the conglomerates at least were built forward by currents of considerable strength, either as a sand-spit, as was suggested by Hicks, or delta-wise. The dips are low, far below the angle of repose for subaquatic accumulation of such materials, and this, together with the exceedingly irregular cross-bedding within the inclined beds, suggests that the material must have been in part distributed by submarine currents.

THE HOCKING VALLEY CONGLOMERATE FACIES

Extent and thickness.—The conglomerate area traversed by the Hocking Valley has been the more closely studied. It lies far enough west on the outcrop belt that the most of its structure can be observed, whereas the Toboso area lies so near the eastern margin of the Waverly belt that only the upper 100 feet of the Cuyahoga are shown.

This area occupies the central and western parts of Fairfield and the western half of Hocking counties, barely extending into Vinton County. The southwestern part of Licking and the eastern margin of Franklin should also be assigned to it. Along its western

¹ *Am. Jour. Sci.*, 3d ser., XVI (1878), 217.

² *Bull. Sci. Lab. Dennison Univ.*, II, Part 1 (1887), 9, 10.

margin it has a length of 45 or 50 miles, its maximum width is about 20 miles. In the southeastern and eastern portions only the upper beds are exposed; in the western and northwestern portions only the lower part remains. The entire thickness is not exhibited in any one section. However, well-records have been easily obtained from the Sugar Grove gas field which extends across it, and have been of much service in unraveling the structure, although little more than generalized impressions can be obtained from the reports coming from the heavy drills there used.

The sandstones of this province are developed along a very distinct axis which trends north-northwest, south-southeast. Along this line of maximum sandstone development, the thickness is 625 feet, decidedly greater than in the Granville shale province to the eastward, and more than twice as thick as it is some miles to the southwestward in the Scioto Valley shale facies where it is about 295 feet. This increased thickness is due to the increased amount of coarse material.

Four members are recognized in the Cuyahoga of this area.

The Lithopolis member is best exposed in the northwestern part of Fairfield County in the vicinity of Lithopolis. The name is newly proposed. It is a series of *thin, horizontal, interbedded sandstones and shales*. The fact that they are horizontal is to be emphasized. The sandstones are usually light gray or bluish in color, moderately fine grained, and evenly bedded. The beds are usually several inches and sometimes two or three feet thick. The shales are argillaceous, and usually, but not always, somewhat sandy; they are commonly gray in color. Carbonaceous material may be present at times sufficient to darken the gray. The sandstones and shales, on the whole, are about equal in amount, although at various horizons one may dominate the other and the sandstones appear to be considerably in excess in the upper part.

The thickness varies from 118 feet to at least 140 feet and possibly 180 or 200 feet between Lithopolis and Chestnut Ridge two miles to the eastward. It is overlain at these localities by a massive coarse, yellow sandstone which is wholly different from those of the Lithopolis member. To the southward, beneath the central portion of the Hocking Valley province, the Lithopolis

member is entirely below drainage but the well-drillers invariably report from 100 to 200 feet or even more of "shale" at the base of the Cuyahoga. This appears to be largely the Lithopolis member, but the records of drillers are usually difficult to interpret, and it does not follow that the entire "shale" bed reported is Lithopolis. The fact that it is reported as shale also need not be disconcerting, as a series more than half made up of sandstone might be so reported. Nor is the reported variation in thickness necessarily a fact; this interval is never measured by the drillers and is almost always given from memory.

Prosser and Cumings have described the Lithopolis occurrences in minute detail and also similar strata from the lower part of the Cuyahoga in eastern Franklin and western Licking¹ counties. Those of the two last localities have not been examined by the writer, but they appear to be of exactly the same type as those at Lithopolis. They have separated off the lower 50 feet of the beds here called Lithopolis and correlated them with the Buena Vista member, or lower 50 feet of the Cuyahoga according to Orton. Since there is no member in central or southern Ohio so limited which is of any significance, stratigraphic or otherwise, the name Buena Vista has been limited in the present work to the principal quarry stone at Buena Vista in the Vanceburg facies from which it was originally derived, and its stratigraphic equivalent cannot as yet be detected and indeed is probably not recognizable in the Hocking Valley conglomerate area. The stratigraphic horizon of the Buena Vista member, as hereinafter defined, will fall in the Hocking Valley facies at least as high as the middle of the Cuyahoga and possibly higher.

The Fairfield member is a series of alternating sandstone and shale beds which quite frequently show initial dips to the northward of two to six degrees. The sandstones when typically developed are coarse, reddish yellow, brown, or bluish gray, sometimes pebbly, and quite commonly are found in massive members 20-60 feet thick with intervening shaly members of similar thickness. The shale strata, however, are themselves formed of thin interbedded sandstones and shales, the former likely to be very coarse,

¹ *Am. Geol.*, XXXIV (1904), 335-58.

even when thin. The features which characterize the member are the *alternating coarse sandstones and shale, the former often massive and thick*, and the *low initial dips*. At some localities there are no shales and the bedding is not always inclined. The last seems particularly true in the northern part of the area. The member ranges from 200 to 330 feet in thickness, but exact figures are impossible.

The Black Hand member is the principal cliff-forming member of the Cuyahoga, and the beautiful scenery of Fairfield and Hocking counties is chiefly the result of its resistance to erosion. It is a massive coarse sandstone or conglomerate and is distinguished from the underlying Fairfield member by the *absence of shale* (very rarely single beds an inch or two thick may be observed) and the increased prominence of its structural features, notably the *steeply inclined bedding* (10° to 20°), the numerous erosion planes, abundant cross-bedding, etc. Its thickness is usually about 100 feet, but may reach 150 feet over the center of the province.

Areally, this member extends laterally beyond the lower members, whenever it can be followed far enough to determine the point. It persists to the eastward with complete loss of structure except normal horizontal bedding into the eastern part of Fairfield County until it passes below drainage, where it is frequently reported in wells with "shales" below it. It is found capping the hills almost as far west as Amanda (Fairfield County) and Tarleton (Pickaway County) but beyond that it is removed by erosion. It is not found more than three or four miles north of Lancaster, the hills beyond that point falling away to lower elevations.

In the southwest corner of Hocking County (Salt Creek Township) and the northeast corner of Ross, and in the western townships of Vinton County, the horizon of the Black Hand is so low in the hills that its passage westward, first into sandstones and then into the shales of the Cuyahoga, can be traced with ease. A marine fauna appears in the sandstones just east of where they pass into shale. The transition has been traced at several points, sufficient to show that the zone of transition extends a distance of 15 miles in a south, slightly southeasterly direction from near the extreme northeast corner of Ross County to near Raysville on the

south line of Vinton County. It has not been traced into Jackson County where a few miles farther to the southward it must pass below drainage.

Over the center of the province, the Black Hand is a coarse pebbly sandstone with occasional beds of conglomerate. The pebbles, all quartz, seldom exceed an inch and a half in diameter. The most striking feature of the member is the bedding, which is inclined at angles ranging commonly from 10° to 20° and sometimes reaching 25° or even more. This structure is much more prominent on the eastern side of the area. This inclination is found throughout most of the thickness of the Black Hand, only the topmost 10-25 feet lying horizontally. The inclined beds correspond in a way to the foreset beds of a delta, the horizontal beds above to the top-set beds. The inclination is almost always toward the northward or at least with a northerly component.

When all the features of the Black Hand and Fairfield members over the area of the facies are taken into consideration, it is evident that the members are distinct. Yet it may be difficult to draw the line between them in any given section, especially in the southern part of the area in western Hocking County. It is impossible here to discuss the relation of one bed to the other. Owing to the physical nature of the members, the contact is almost always covered except for short exposures of a few feet at wide intervals. Where the members are well developed there is almost invariably an erosion plane present at or near this contact. But whether this is a plane of unconformity between the two members or is merely another of the commonly observed erosion surfaces, several of which can sometimes be seen in a single outcrop and most of which are obviously local, is not yet fully determined. In any event the erosion plane, if there is an extensive one, disappears near the margin of the facies as the coarse sediments give place to shales, and is believed to be of no great significance. Whether these conglomerate facies be regarded as deltas of a peculiar type or as bar formations, the surface of the accumulation at any given time stood well above the mud floor of the adjacent shale facies and was liable to erosion over portions of its surface under conditions which would not affect the adjoining deeper areas.

G. F. Lamb has described two conglomerate horizons in Wayne County in northern Ohio.¹ Both have the bedding inclined to the northward, and erosion surfaces are recorded beneath each and are described as unconformities. The lower bed is from 2 to 45 feet thick and is about 625 feet above the Berea sandstone. From this it would appear to be near the horizon of the Black Hand member. It may, however, be the Berne member (which in places is Herrick's Conglomerate I recorded by Herrick in northern Ohio) which was also preceded by erosion over the central Ohio conglomerate areas, and which extends areally beyond the Black Hand both in the Granville facies and on the western side of the Hocking Valley facies.

The Berne member, never over 20 feet thick, and frequently only one foot in thickness, is always present and readily recognized, resting on the Black Hand. The term is proposed from numerous outcrops in Berne Township of Fairfield County. In the Hocking Valley region, as in the Toboso region, this bed consists largely of pebbles, but sandstones of moderate coarseness and shales are found in it at some localities. In mapping, its upper limit forms the logical plane to be followed since it usually forms the top of the ledges and the bed is lithologically very like the underlying conglomerates. The contour of the surface of this bed, that is, the surface of the Cuyahoga deposits, is much the same as that of the Black Hand member, but in order to understand the Berne member it is desirable that the top of the Black Hand be distinguished and that the contour of its surface be determined separately from that of the Berne member, thin though the latter be.

The topographic map is essential to the determination of these features, and at the time the field work on this region was done the Lancaster and Logan sheets were the only ones issued covering any considerable portion of the area. The Chillicothe sheet which lies southwest of the Lancaster sheet, covers only a very small area of the transition zone on the extreme western side of the province. Much of the most interesting part of the province in southern Hocking and the western part of Vinton counties lies south of the

¹ "Middle Mississippian Unconformities and Conglomerates in Northern Ohio, *Ohio Naturalist*, XIV (1914), 344-46.

Lancaster sheet and has not been visited since 1910, when it was unmapped.

On the eastern side of the main body of the facies, that is, that portion of it lying west of the Hocking River, the top of the Black Hand dips to the eastward at a rate which varies considerably from point to point, but is much greater than the general regional dip. In north-central Hocking County the dip over much of this side is about 35 feet per mile, but reaches a rate of 119 feet for a distance of a mile on the eastern flank, just west of Hocking River. A few miles north of this, the dip is about 37 feet per mile over the center of the conglomerate area, increasing to an average of 58 feet over most of the eastern flank, but with no indication of the extreme dip observed for the short distance farther south. Along the eastern margin of this steep slope the surface of the Cuyahoga is carried down nearly to the level of the main drainage lines, but after continuing for a short distance thus, it recovers and rises to the eastward in a broad low arch a few miles wide, within which cliffs of Black Hand 40 or 50 feet high are exposed; beyond this to the eastward it sinks rapidly below drainage. This broad low arch is exposed for four or five miles along the Hocking River above Logan and again along Rush Creek in Hocking County several miles to the northward, as well as along the intermediate smaller streams. It is very like a broad, low anticlinal fold with its axis trending in a generally north-south direction. However, it does not appear probable that the doming of the surface is due to gentle regional warping, although this possibility has not been disproved. It seems more likely that this dome is a second smaller conglomerate mass lying a short distance east of, and nearly contiguous to, the main mass, and is, indeed, merely a lobe of the main Hocking Valley area. The structures observed in the exposed portions bear this out, the material being conglomerate with northerly dips. It probably dies out north of Rush Creek, for no trace of it was observed farther north and east of Lancaster where the sandstone loses its pebbles and structures immediately east of the Hocking River, and the surface declines regularly to the eastward. The contour of the upper surface of the Black Hand is thought to be due to the influence of this separate lobe of accumulation, for

the thickness of the entire Cuyahoga is greatest over this lobe and the main conglomerate area and diminishes somewhat in the slight sag between them.

The principal considerations in support of this are: (1) the lack of evidence of any pronounced anticlinal structure in the underlying rocks, although the region has been drilled over for years in the search for gas and oil; (2) the increased thickness of the Berne member in the trough and its diminished thickness over the crests; the same is true to some extent of the next succeeding bed, the Byer member of the Logan.

On the western side of the Hocking Valley province, the inclination of the top of the Black Hand (and with it the Berne member, which is uniformly thin) becomes considerably lessened and the member may even sink slightly to the westward, notwithstanding the general regional rise of the older rocks in that direction. At the Rock House, about 11 miles west of Logan and just south of the south edge of the Lancaster sheet, the elevation of the top of the Cuyahoga, that is the top of the Berne member, is 1,060 feet above sea level. Eight and one-half miles almost due southwest of this point on the Ross-Hocking county line, the same horizon occurs at only 975 feet, a decline of 85 feet contrary to the general regional dip. The decline in the surface of the formation is here clearly due to the westwardly decrease in thickness of the Cuyahoga.

The Berne member differs very decidedly from the conglomerates lower down in the presence of a marine fauna. This is seldom abundant, either in species or in individuals, but the fossils are so widespread, both in the finer beds and in coarse conglomerates, that they may be considered an essential character.

In the region of the Hocking Valley facies, it is found in its simplest form over the central and western portions. Here, with a few exceptions, it is a more or less massive coarse sandstone with abundant pebbles, on the whole always decidedly coarser than the Black Hand, and usually from one to three feet thick. It becomes thinner westward so that it is usually about one foot thick on the western margin of the region. It even extends westward for a few miles beyond where the Black Hand becomes shaly and in

eastern Ross County is found resting on typical Cuyahoga shales, itself reduced to a horizon of a few inches of soft clay shale or clay ironstone with many small quartz pebbles imbedded therein. It does not pass into sandstone before its final disappearance; it is a pebble bed up to the point of its disappearance.

The Berne member attains its greatest known thickness in the trough between the two domes of conglomerates mentioned above, where, near Enterprise in Hocking County, it is at least 16 and probably 20 feet thick. It there consists of many thin beds of fine pebbles alternating with thin beds of sandstone of varying coarseness, the whole suggesting aggradation of different kinds of material brought by continually shifting currents from the more exposed, shallower portions of the adjacent conglomerate masses to the more sheltered deeper water between them. The member, here and over its entire area, can best be interpreted as the concentrate of pebbles and coarse sand which resulted from the reworking of the top of the earlier deposits by wave and current action. This must have happened soon after the completion of the deposition of the underlying conglomerates and while they were but slightly consolidated.

It is not certain whether the Berne member should be considered the topmost member of the Cuyahoga or the base of the Logan formation. Lithologically it falls readily with the Cuyahoga conglomerates, and in the event of mapping the region it will prove a most convenient upper boundary. There is very good reason to believe, however, that from the point of view of historical succession it belongs with the Logan. This conclusion is supported by several considerations. (1) The base of the bed is sharp, and in places is undoubtedly a plane of erosion as where, near Logan, the horizontal beds of the top of the Black Hand have been removed and the Berne member truncates the inclined beds of the Black Hand. (2) There is occasionally a transition from the Berne member to the Logan although never more than a few inches thick, as in the railroad cut at Hanover (Licking County) and at localities in Hocking County. (3) Beds very like the lower member of the Logan, although usually somewhat coarser, are frequently present in the Berne member east of the Hocking Valley province. (4) The

bed is a marine conglomerate, as shown by the general occurrence of marine fossils in it. Although the body of the Cuyahoga conglomerates is not to be considered as typically non-marine, it is evident, from the lack of all fossils except trails, that it was a very specialized type of marine deposit. The Berne member marks the resumption of conditions under which marine life could exist. (5) The faunas found in the Berne show much closer relationships to those of the Byer member of the Logan than to those of the Black Hand in its marginal transition phases. These faunas do not, however, appear to indicate an essential difference in age. The evidence goes to show that the Black Hand and Logan faunas were contemporary and their distinctness is due to facial differences. The fauna of the Berne member thus indicates the existence of faunal conditions like those of the superjacent Logan rather than those of the subjacent Black Hand.

In concluding the consideration of the Hocking Valley region, it remains to be said that the source of its material must have been in the same direction as that of the Toboso province. The gentle northeastward inclination of the sandstone beds of the Fairfield member on the east side, their occasional westerly dips on the west side, the bedding of the Black Hand sharply inclined to the east, northeast, north, or west, when considered with the southeasterly trend of the axis and the shale areas to the east and west, clearly indicate that the source of the material was to the southeast.

The material of the Cuyahoga sandstones in both the Hocking Valley and the Toboso provinces is quite pure quartz sand and pebbles. Close examination of the crushed rock from the Black Hand shows some small amounts of feldspar and more abundant kaolin, the latter clearly indicating the once greater percentage of the former, but it appears that the material has been much worked to bring it to its present degree of purity. It is true, however, that the samples so examined were selected for their purity in connection with work on glass sands. In the Fairfield member and less rarely in the Black Hand, beds may occasionally be found in which the kaolin is so abundant as to be readily detected in the field without the aid of a lens. These beds must have been quite high in feldspar originally.

THE GRANVILLE SHALE FACIES

Extent and thickness.—This facies lies between the Toboso and Hocking Valley conglomerate facies and is an area in which shales accumulated to a much greater extent than in the other two. It is of unusual interest because it was in the Licking County outcrops of this facies that Herrick worked out certain of his faunal horizons and from which he described many species; furthermore the succession of formations found there, as interpreted by the workers of the time, has been adopted during the past decade as the typical Waverly column of Ohio.

The boundaries of the facies are only partially determined and must be largely inferred at present. In general it appears to occupy most of the eastern half of Fairfield and the western part of Perry counties, where it is almost entirely below drainage, and the central part of southern Licking County. The Toboso conglomerate area lies to the eastward in Licking County and, presumably, also in Perry County, but deep under cover in the latter. The Hocking Valley conglomerate area lies to the westward in central Fairfield County, and its hypothetical northward extension in northern Fairfield and western Licking counties, since removed, is supposed to have limited the Granville province in that direction. To the southeastward, it is partially limited by the small conglomerate lobe on the eastern side of the Hocking Valley area, and it probably does not extend much farther in that direction under the Coal Measures cover before it is bounded by coarse sediments extending continuously from the Toboso to the Hocking Valley facies. It has not been traced to the northward and northwestward, but it probably extends across the northern part of Licking County and somewhere in that direction it formerly united with the shale deposits of the Cuyahoga which, from theoretical considerations, must have extended around the northern end of the Hocking Valley conglomerate facies and must have been continuous with the shales of the Scioto Valley shale facies.

Unfortunately the three northern townships of Fairfield County are almost without exception very heavily drift covered, a buried pre-glacial valley; the northwestern portion of Perry County, although underlain by rock, shows very few outcrops, and at the

most, only the topmost beds of the Cuyahoga are shown. In addition, Licking County southwest of Granville is practically unexamined by the writer.

Wherever this facies has been observed, either in the outcrops or by means of well-records, its sediments show the effect of the conglomerate areas on either side. Their thickness, while somewhat less than in the adjacent conglomerate facies, is much greater than in the Scioto Valley shale facies, and the sandstone content appears to be decidedly greater. As has been stated, the thickness of the Cuyahoga in the Hocking Valley facies is from 600 to 625 feet. Passing eastward this gradually decreases in the wells to about 500 feet just west of Bremen in Fairfield County (Myers well). A few miles to the northward at Rushville, an approximate determination with several somewhat uncertain factors gives 535 feet. At Newark, yet farther north in Licking County, well-records indicate about 570 or 575 feet, and at the Everett quarry over the Toboso facies, due east of Newark, it is 588 feet thick. This series of observations extends in an irregular oblique line north and northeasterly, entirely across the Granville province. Newark, from various considerations, appears to lie on the transition to the Toboso facies.

The Black Hand member appears to be generally present along the length of this line, although there are often unknown covered intervals of several miles for which no well-records or outcrops are known. It appears to be from 50 to 100 feet thick and is considerably changed from its conglomerate phase; it consists largely of coarse or moderately coarse sandstones, with occasional shaly beds, and sometimes carries fossils. Just east of Rushville, there is good evidence from wells that the Black Hand is largely represented by what the drillers report as shale.

Due westward from Newark a change in the nature of the Black Hand can be observed in the surface outcrops. Within four miles it passes largely into sandy shales; sandstone beds are present, sometimes two or three feet thick, but they are irregular and may pinch out entirely in a few feet. This passage to shales exactly parallels that observed at many points on the western side of the Hocking Valley facies in Hocking, Vinton, and Ross counties.

Conditions of outcrop, and limited observation, however, have not permitted the tracing of this passage farther in Licking County. The nature of the Black Hand horizon at Granville, two or three miles yet farther west, is not known, but a further disappearance of the sandstones is anticipated. In fact, so firm is this conviction that no hesitation has been felt in adopting the name Granville for the shale province although very little of the Cuyahoga was seen by the writer in that vicinity. Four or five miles yet farther to the westward on Moot's Run, the fossiliferous beds of the Cuyahoga, there largely a shale but with considerable sandstone, furnish an excellent collecting ground; whether they are Black Hand, shale facies, or belong to the underlying Raccoon member is not yet determined.

Raccoon member.—Below the Black Hand near Newark there are some 20 or 30 feet of sandy or clay shales with numerous thin sandstones, sometimes quite fossiliferous; the remainder of the Cuyahoga, here and other points known to the writer, is below drainage and is commonly reported as shale by the drillers, but an occasional more careful record shows that the next underlying 200 feet carry many beds of sandstone, sometimes 3 to 6 feet thick, with thicker shale beds. The lowermost 200 feet, more or less, appear to consist almost wholly of shale. In 1878, when Hicks proposed the name Black Hand, he used the name Raccoon for the shales between it and the Sunbury shale. When, later, the central Ohio and northern Ohio Waverly formations were correlated, it appeared that this term was synonymous with Cuyahoga and it was dropped. It may be brought forward, temporarily at least, to designate that almost unknown thickness of shales and sandstones below the Black Hand member. So little is known of these at present in the Granville facies that it cannot yet be safely urged as a permanent formational name.

The Berne member.—Little need be said of this member in this province. It is a pebble bed of essentially the same composition as over the two conglomerate provinces, except that beds of finer-grained sandstone are frequently intercalated. Between the two conglomerate facies there is an interval of 20 miles in northern Fairfield and southern Licking counties across which its presence

has not been shown because of drift-covered outcrops or its occurrence below drainage, but it is probably present. Followed westward from the Toboso province it can be traced readily into the Conglomerate I of Herrick in the section in Quarry Run at Newark. At the Dugway three miles west of Newark, where the Black Hand member is largely shaly, the Berne member is 10 feet thick and the pebbles are noticeably smaller than to the eastward.

The section in the Quarry Run at Newark has become the classic section of the upper Waverly of Ohio. Prosser's description of this section¹ in which he adopted the stratigraphic units used by Hicks² and Herrick has been accepted as the standard column of the upper Waverly, and most of the correlations that have been made with the upper portion of the Waverly have been based thereon. It is, indeed, the only section of this portion of the scale which has been accurately described. It appears, however, that the Black Hand has been made to include too much in the descriptions of this section. Only the lower 60 feet are the equivalent of the Black Hand as that member is interpreted in the present work. Conglomerate I of Herrick, which was placed by Prosser 29 feet below the top of the Black Hand, is the Berne member and the top of the Cuyahoga. These 29 feet are to be correlated with the Byer member and the lower part of the Allensville member of the Logan. Prosser's error is the result of his having accepted Hicks's statement that all of these beds were the equivalent of his (Hicks's) Black Hand at Clay Lick and Toboso. To Hicks belongs the credit of having first appreciated the passage of the Black Hand conglomerates into finer-grained sediments to the westward. If Orton had appreciated the significance of Hicks's discovery, much of the confusion of later years would have been spared.

¹ *Jour. Geol.*, IX (1901), 221-26; *Am. Geol.*, XXXIV (1904) 358-61.

² *Am. Jour. Sci.*, 3d ser., XVI (1878), 216.

[To be continued]